EXPANSION OF THE RAW MATERIAL BASE

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USE OF KHAKASS FELDSPAR IN PRODUCTION OF CERAMIC TILES

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The use of feldspar rock (orthophyre) and feldspar wastes of the Molibden Joint Stock Company (stripping pegmatites and tails resulting from ore concentration) in ceramic mixture compositions is investigated. The dependence of sintering and phase formation on the type and quantity of the feldspar component and the amount of cullet in the mixture is established. A diagram for selection of ceramic mixture compositions with the required sintering degree is developed. The properties and phase composition of tiles with the optimum amount of the feldspar components are studied.

One of the main problems in the development of ceramic mixtures for accelerated firing is the selection of flux additives, preferably from local sources [1]. The present paper describes the study of feldspar material from Khakassia and the adjacent southern districts of the Krasnoyarsk Region with the view of using it in combination with the local clays.

The investigated feldspar rocks include orthophyre from the Kuraginskii deposit and two types of feldspar waste from Molibden JSC: the stripping and surrounding pegmatites sent to the dump in ore mining and the feldspar tails (Sorskii sand) resulting from ore processing and hydraulically deposited to the tailings storage. The chemical composition of the feldspar material is shown in Table 1.

Orthophyre is a magmatic rock bedded in massifs which has a homogeneous composition and is easy to mine. The rock has an increased content of potassium, sodium, and iron oxides. The orthophyric minerals include potassium feldspars in the form of orthoclase and microcline, albite, anorthite, quartz, hematite, and calcite.

The pegmatites from the dump are a mixture of rock fragments of different sizes up to 50 kg and are accessible for extraction. While the content of sodium and potassium oxides in the pegmatites is nearly the same as in orthophyre, the iron oxide content in the pegmatites is 9 times lower. The pegmatite minerals are virtually the same as in orthophyre: they include orthoclase, albite, anorthite, quartz, calcite. However, judging from the relative intensity of the maximum phase reflections on the x-ray patterns of the feldspars components (Table 2), the pegmatites have a higher content of albite and a lower content of quartz and anorthite compared to orthophyre, and do not contain hematite.

The concentration tails from the Molibden JSC (the Sorskii sand) arrive at the tail deposit in the form of sand. Its

TABLE 1

Raw material	Mass content, %								
	SiO_2	Al_2O_3	TiO_2	Fe_2O_3	CaO	MgO	Na_2O	K_2O	calcination loss
Orthophyre	67.81	14.38	0.28	5.17	1.19	0.71	4.34	5.46	0.70
Pegmatite	69.87	17.12	0.17	0.71	0.94	0.32	4.84	5.62	0.41
Sand	62.82	15.90	0.50	3.52	4.07	1.66	4.20	3.68	2.13

TABLE 2

Raw material	Relative intensity of the maximum phase reflexes						
	albite (3.76 Å)	anorthite (3.77/3.74 Å)	quartz (3.34 Å)	orthoclase (3.25 Å)	albite, anorthite (3.17 Å)	hematite (2.69 Å)	calcite (3.07 Å)
Orthophyre	1	–	8	3	10	1.0	0.5
Pegmatite	3	–	3	10	5	–	0.2
Sand	–	1/1	10	3	9	0.5	1.0

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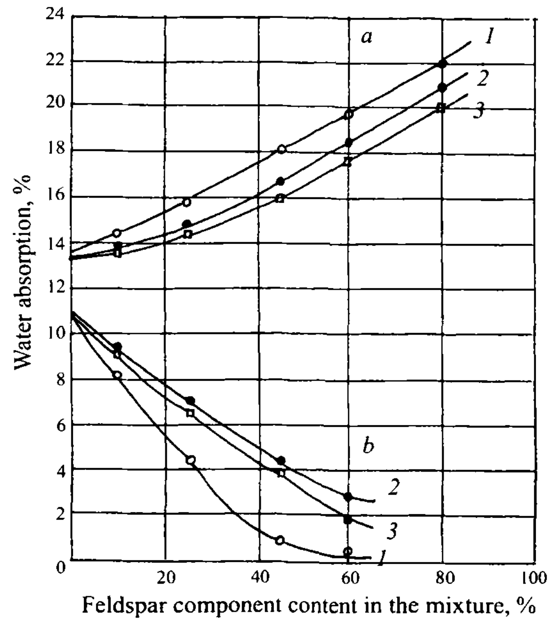

Fig. 1. Effect of the feldspar component of the sintering of the Izykhskii clay (*a*) and the mixture of clay with 15% cullet (*b*) at the firing temperature of 1100°C: *1*) pegmatite, *2*) orthophyre as the feldspar material; *3*) Sorskii sand.

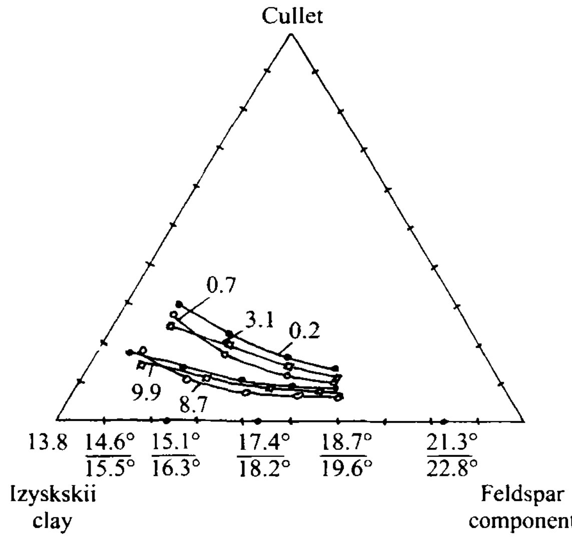

Fig. 2. Diagram of variation in the water absorption of samples after firing at 1100°C depending on the component ratio in the mixture: ●) orthophyre as the feldspar material; ○) pegmatite; □) Sorskii sand

granular composition varies from very fine sand containing 34.5% dustlike and argillaceous particles to fine sand with the content of sand particles equal to 13%. The chemical composition of the sand is homogeneous, it contains less potassium and sodium oxides than the orthophyre and pegmatite do, less iron oxide than orthophyre does, but significantly more iron oxides than pegmatites. The mineralogical composition of the sand is nearer to orthophyre. The main phases of the sand are orthoclase and albite. At the same time, according to the x-ray phase analysis data (Table 2), the sand contains more impurities of quartz, anorthite, and calcite than orthophyre does, less hematite, and mica as well is present here.

In order to experimentally assess the efficiency and determine the quantitative content of the feldspar components in ceramic mixtures, we investigated their effect on sintering and phase formation of the Izykhskii montmorillonite-kaolinite clay (Khakassia), including combinations of clay and cullet. The amount of the feldspar components added to the clay varied over a wide range (from 10 to 85%), which was made possible due to the high plasticity of the clay (19 – 25).

Sintering was studied on cylindrical samples 25 mm in height and 25 mm in diameter molded by semidry compression. The components were milled to no more than 5% residue on a No. 005 sieve, and the samples were compressed under a pressure of 25 MPa.

The sintering of the Izykhskii clay with the feldspar components deteriorates up to the firing temperature of 1100°C. The higher the content of the pegmatite, orthophyre, or sand in the clay, the worse the sintering is. However, upon introduction of cullet as flux, the feldspar components exercise a fluxing effect on clay sintering. The sintering effect depends on the type and the quantity of the feldspar component and the content of cullet in the mixture. With a cullet content equal to 15%, the pegmatite has the strongest fluxing effect on clay sintering and the effect of the orthophyre is the weakest. As the content of the feldspar component increases, its sintering effect on the clay intensifies (Fig. 1).

With an increase in the content of the feldspar component and a simultaneous decrease in the amount of cullet in the mixture, the same sintering effect can be obtained (Fig. 2) The content of the feldspar components in the mixture can vary from 10 to 60%, that of the cullet can vary from 5 to 35%, depending on the type and quantity of the feldspar component and the required degree of sintering. In each specific case the ratio of the components can be determined by the standard procedures for three-component diagrams.

The x-ray phase analysis made is possible to clarify the essence of the sintering process of the clay with the feldspar compo-

TABLE 3

Component	Content in mixtures, %						
	1	2	3	4	5	6	7
Izykhskii clay	55	30	60	35	55	45	100
Orthophyre (pegmatite or Sorskii sand)	30	60	30	60	30	50	–
Cullet	15	10	10	5	5	5	–

nents. Thus, the x-ray patterns of the two-component mixtures of clay with orthophyre, pegmatite, or sand exhibited only insignificant variations in the basic lines of these components. Therefore, the interaction between the clay and the additives which could be accompanied by sintering is absent. The polymorphic transformations of the feldspar and quartz [2] introduced in the mixture as components dilate the samples and increase their water absorption (Fig. 1).

The x-ray patterns of the three-component mixtures show a decrease in the relative intensity of albite, orthoclase, hematite, and quartz, and mullite lines appear. This points to intensification of liquid phase formation under the effect of the cullet, due to the involvement of the albite, orthoclase, and hematite contained in the feldspar components with subsequent dissolution of quartz and the argillaceous component of the mixture. A higher content of albite in the pegmatite determined its stronger effect on the sintering of ceramic mixtures (Fig. 2). At the same time, the presence of orthoclase in all feldspar components, which expands the sintering interval [3], makes it possible to avoid warping of samples with minimal values of their water absorption. The quoted investigation results were taken as the basis for determining the ceramic tile compositions (Table 3).

TABLE 4

Parameter	Mixture samples						
	1	2	3	4	5	6	7
Firing temperature, °C	1090	1090	1070	1070	1070	1070	1070
Water absorption (%) on introduction of:							
orthophyre	3.4	2.9	8.7	9.1	12.8	13.4	12.2
pegmatite	1.6	1.8	5.8	4.9	11.6	11.7	–
Sorskii sand	1.9	2.5	6.9	7.2	12.5	12.3	–
Shrinkage (%) on introduction of:							
orthophyre	5.8	5.1	4.4	3.9	2.1	1.8	1.9
pegmatite	6.5	5.8	4.8	4.5	1.9	1.8	–
Sorskii sand	6.1	5.6	3.3	3.1	1.9	1.7	–
Bending strength (MPa) on introduction of:							
orthophyre	32	31	28	24	19	19	11.9
orthophyre	34	32	27	25	21	20	–
Sorskii sand	32	32	27	24	20	29	–
Heat resistance, °C	130	130	130	130	130	130	130
Moist expansion, %	0.09	0.08	0.08	0.09	0.08	0.09	0.1
Cold resistance, cycles	> 50	> 50	> 50	> 50	> 50	> 50	49
Color on introduction of:							
orthophyre	Brown						Light pink
pegmatite	Gray						
Sorskii sand	Brown						

The analysis of the physicotechnical parameters of the samples (Table 4) indicated that by changing the ratio between the feldspar components and the cullet it is possible to obtain floor tiles (mixtures 1 and 2), facade tiles (mixtures 3 and 4), and decorative tiles (5 and 6). The samples exhibit high strength, high cold resistance, and low values of moist expansion. The shrinkage of the samples made of mixtures with feldspar components is higher than the shrinkage of the samples made of pure clay material. With water absorption equal to 2.9 – 3.4%, the shrinkage of the samples is 5.8 – 6.5%. However, the obtained shrinkage values do not go beyond the standard values typical of ceramics with a similar degree of sintering made on the basis of other fluxes [3].

The high physicotechnical parameters of the samples made of the mixtures with feldspar components are determined by their phase composition after the final sintering. The main crystalline phases of the ceramics include a mullite-like phase, feldspars, and quartz. The feldspar type depends on the type of the feldspar component. When orthophyre is used, orthoclase and pegmatite prevail, for pegmatite, it is a mixture of albite and orthoclase, and in using sand, the feldspar is represented by anorthite.

The ceramic mixtures with 30% pegmatite and 15% cullet (mixture 1), 30% sand and 10% cullet (mixture 3), 60% orthophyre and 5% cullet (mixture 5) were tested in the production of floor, facade and interior decoration tiles on the accelerated firing line at the Ceramic Tiles Works of the Khakasstroimaterialy JSC.

The firing temperature for the floor tiles was 1090°C, the facade and interior decoration tiles were fired at 1070°C, and the firing duration was 60 min.

The properties of the tiles manufactured at the production line meet the standard requirements and support the results of the laboratory studies.

Thus, feldspar rock (orthophyre) from the Kuraginskii deposit and feldspar wastes from the Molibden JSC in the amount of 30 to 60% can be used in combination with substandard clays in the production of various purpose tiles.

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